

# Shunt Active Filter Command Designed in LabVIEW

Caius Panoiu, Raluca Rob, Ioan Baciu, Manuela Panoiu

**Abstract**—This paper represents a study about the command of an active filter with IGBT transistors using a data acquisition board. The main purpose of this active filter is to reduce the harmonic distortion in power distribution generated by an electro thermal installation with electromagnetic induction. IGBT transistors are controlled using a command scheme designed in LabVIEW.

**Keywords**—Data acquisition board, electro thermal installation, harmonic distortion,

## I. INTRODUCTION

The major causes of power quality problems are due to the wide spread application of static power electronic converters, saturable devices, fluorescent lamps and arc furnaces. Some of the adverse effects of poor power quality are reduced motor life, increased losses, mal-operation, electromagnetic interference, increased heating and faulty timing signals [2], [7]. Electro thermal installations with electromagnetic induction cause serious problems in power quality field. In order to respect the imposed limits for harmonic distortion is necessary to connect power conditioning devices at the interface with the power distribution.

The hardening electro thermal installation presented in figure 1 is composed by a converter CTC100K15 [8] and an inductor designed for hardening the materials. CTC100K15 has the following electric characteristics:

- supplying voltage 3x400V, 50Hz;
- rated current 27A;
- consumed power at high frequency 15kW;
- voltage at medium frequency 500Vac.

The hardening inductor is supplied from two high frequency toroidal transformers:

- T1: 660/500V, 40kVA, 70-100 kHz;
- T2: 150 kVA, 70-120 kHz with primary winding

Caius Panoiu - Electrical Engineering and Industrial Informatics Department, Timisoara Polytechnical University, Faculty of Engineering Hunedoara, (e-mail: caius.panoiu@fih.upt.ro)

Raluca Rob - Electrical Engineering and Industrial Informatics Department, Timisoara Polytechnical University, Faculty of Engineering Hunedoara, (e-mail: raluca.rob@fih.upt.ro)

Ioan Baciu - Electrical Engineering and Industrial Informatics Department, Timisoara Polytechnical University, Faculty of Engineering Hunedoara, (e-mail: ioan.baciu@fih.upt.ro)

Manuela Panoiu - Electrical Engineering and Industrial Informatics Department, Timisoara Polytechnical University, Faculty of Engineering Hunedoara, (e-mail: manuela.panoiu@fih.upt.ro)

voltage of 500V and variable transformation ratio.

The electro thermal installation contains three coil shape inductors for hardening process.

In figure 2 are depicted the variation of the most representative electrical parameters that characterize the functioning of the electro thermal installation [3]. There were used the following notations:

-  $V_{Sa}$ ,  $V_{Sb}$ ,  $V_{Sc}$  [kV] are phase voltages in the primary winding of transformer that supplies the installation.

-  $I_{Sa}$ ,  $I_{Sb}$ ,  $I_{Sc}$  [A] are phase currents in the primary winding of power transformer that supplies the installation.

-  $V_a$ ,  $V_b$ ,  $V_c$  [kV] are phase voltages in the secondary winding of transformer that supplies the installation.

-  $I_a$ ,  $I_b$ ,  $I_c$  [A] are phase currents in the secondary winding of power transformer that supplies the installation.

It can be observed that the currents in primary and secondary winding of power transformer are deeply distorted. In order to decrease the THD value, the authors designed an active filter with six IGBT transistors commanded using LabVIEW program.

## II. IGBT COMMAND DESIGNING

The main function of a shunt active filter (SAF) is compensation of the load harmonic current, so that active filter confines the load harmonic current at the load terminals, hindering its penetration into the power system. It draws an additional harmonic current in order to keep the load terminal voltage sinusoidal [4], [5], [6]. Due to the non-linear characteristics of power electronics loads, THD of source current and terminal voltage fall below of IEEE 519 standard and in principle SAF is used to inject a current equal in magnitude but in opposite phase to residual current to achieve a sinusoidal current wave in phase with the supply voltage.

### *Principle of operation*

To distorted currents  $i_1$ ,  $i_2$  and  $i_3$  from figure 3 is applying the Fast Fourier Transformer in order to extract from each signal the first order component (fundamental harmonic current). These components are subtracted from distorted currents to obtain the residual component on each phase  $i_{rez1\pm}$ ,  $i_{rez2\pm}$ ,  $i_{rez3\pm}$ . The both alternances of the residual components are introduced in a PWM system that commands a shunt active filter with 6 IGBT transistors [1]. The resulting currents  $I_{rez1\pm}$ ,  $I_{rez2\pm}$ ,  $I_{rez3\pm}$  are injected in power system using a current transformer in order the system currents become sinusoidal.

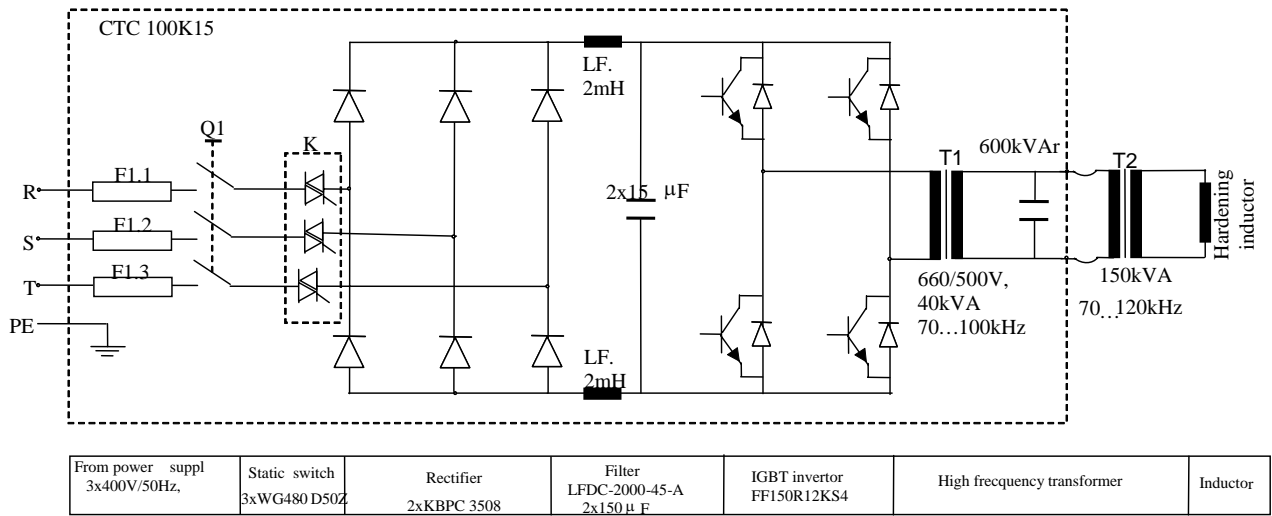


Fig. 1. Hardening electro thermal installation.

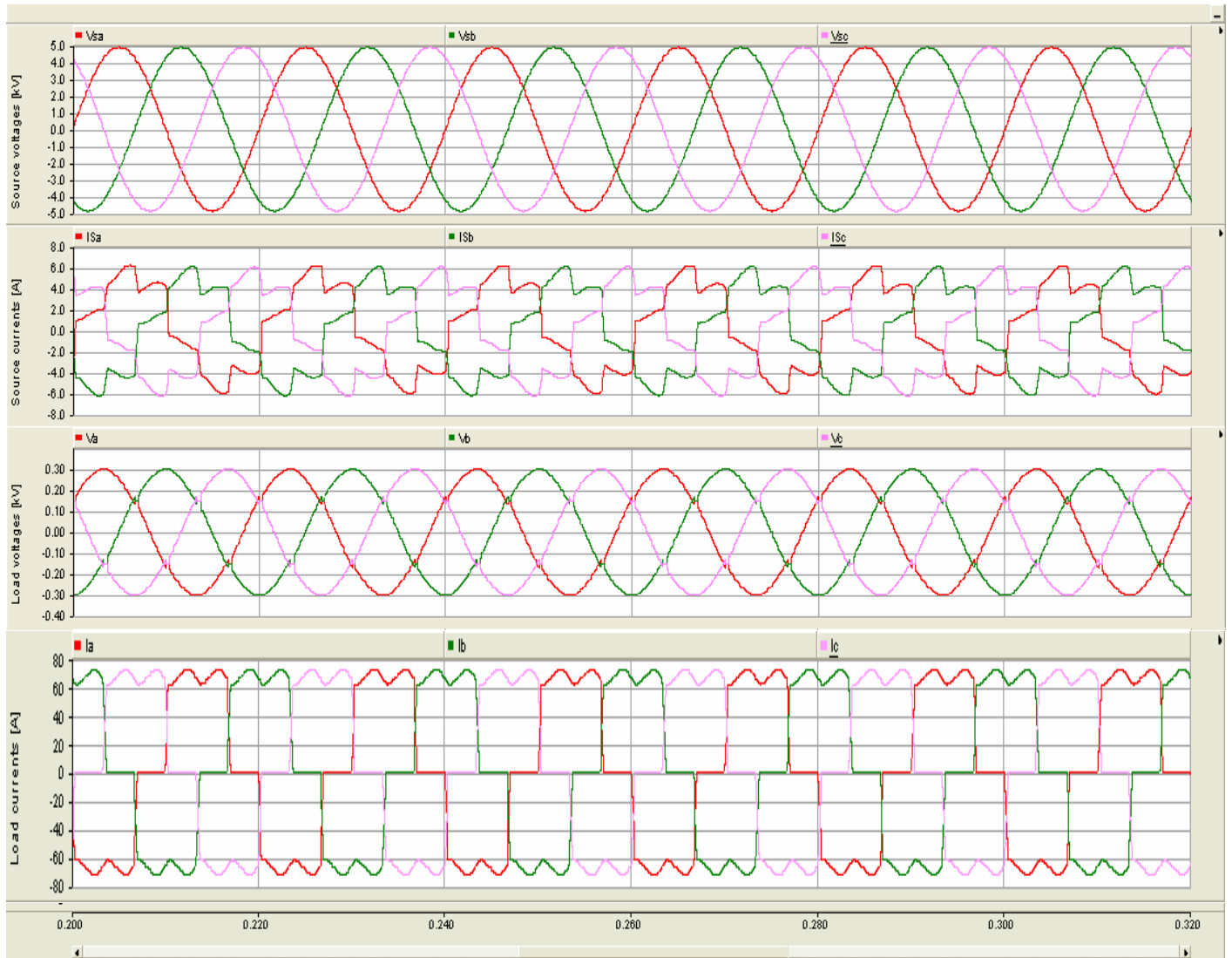


Fig. 2. Simulations results of time variations of source and load voltages and currents.

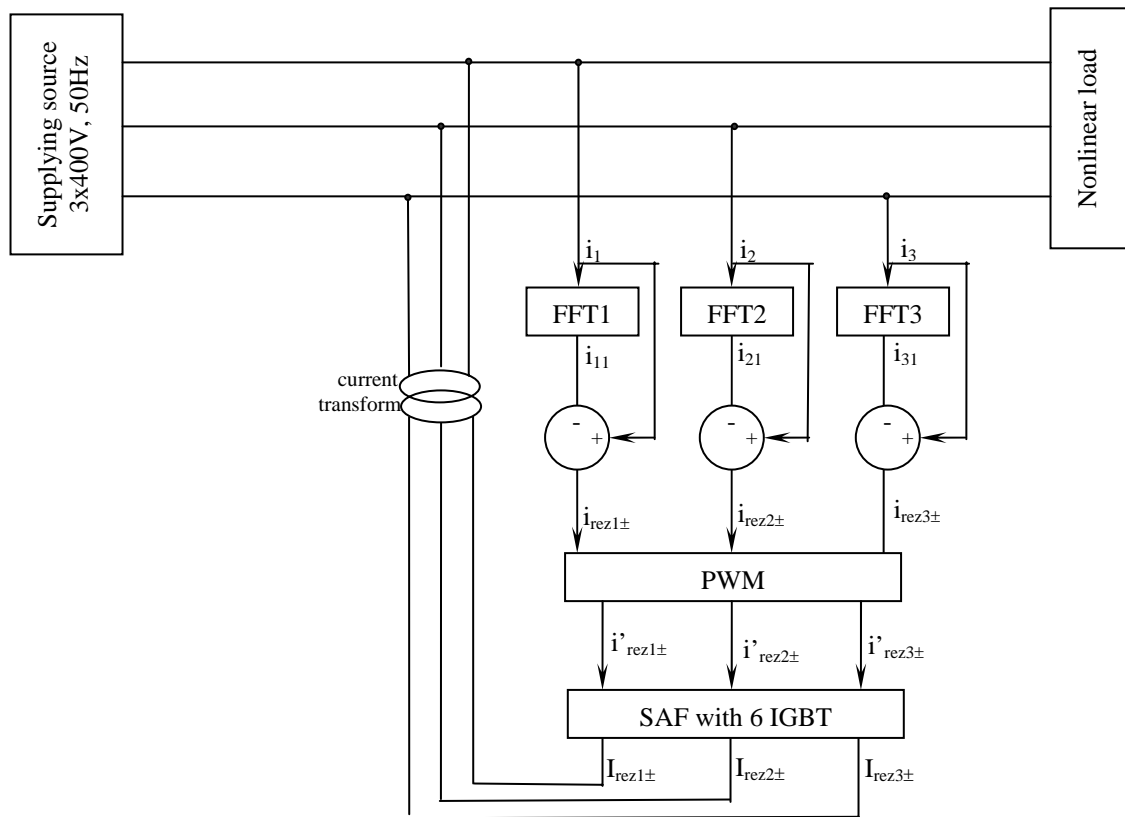


Fig. 3. Principle of shunt current compensation.

In scope of acquiring the input signals, the authors used a data acquisition board NI 6221 with the following characteristics [9]:

- 16 analog inputs, 250 kS/s, resolution 16 bits
- 2 analog outputs, 740 kS/s, resolution 16 bits
- 10 digital I/O compatible TTL
- 2 counter/timers on 32 bits
- digital trigger
- integration with software components LabVIEW, CVI, Measurement Studio for Visual Studio NET.

After reducing their amplitudes with current transformers, the distorted currents  $i_1$ ,  $i_2$  and  $i_3$  are acquired using 3 analog inputs. Figure 4 presents the scheme that commands the IGBT transistors for one phase.

Acquiring signals can be made using DAQ Assistant block. Fast Fourier Transform is done with Spectral Measurement block. Signals are acquired with  $N=4000$  samples / period and a sampling rate  $f=200\text{kHz}$ .

In this paper the authors simulated the distorted currents using a signal generator from LabVIEW library.

Simulation of the distorted signal is made using a square signal generator from LabVIEW library. The parameters of this signal are introduced using numeric controls (rotating, boolean buttons) placed on front panel.

The generated signal has a square waveform with variable duty cycle. The amplitude and frequency can be adjusted from a rotate button placed on front panel.

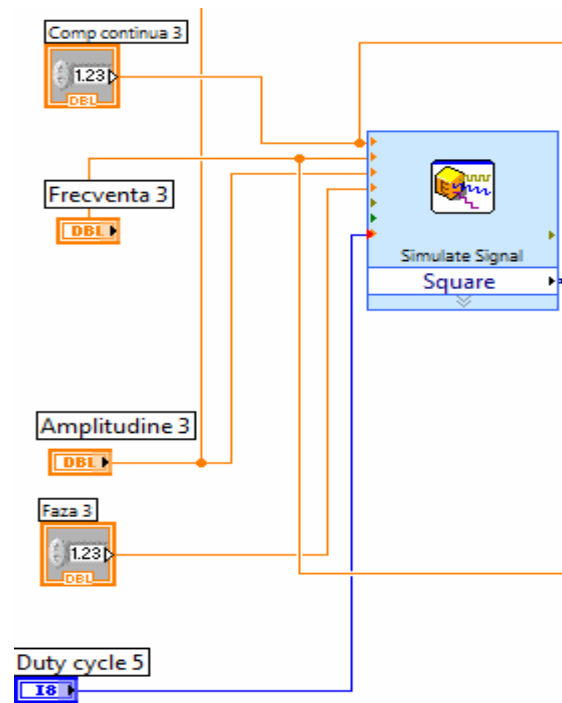


Fig. 4. Square signal generator.

The frequency of the distorted signal is 50Hz. Duty cycle for the distorted signal is variable and can be adjusted using a rotating button place don front panel.

Fast Fourier Transformer is realised using Spectral Measurement block. From harmonic spectrum generated by this block, using Index Array function, it can be extracted the fundamental component of the input signal.

This component become sinusoidal using another signal generator that generates a sinusoidal signal with the same frequency and the same offset with the square signal generated in upstream, but having the amplitude equal with fundamental component that is extracted from FFT block and with phase added with 90°. A subtracting block makes the difference between the distorted signal and its fundamental component, resulting a residual signal irez.

In figure 5 it can be observed the separation of the fundamental component.

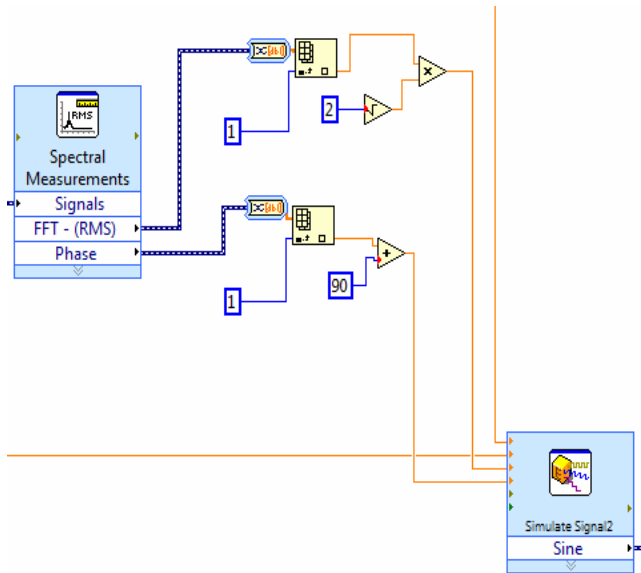


Fig. 5. Separation of the fundamental component.

Dynamic data of the residual signal are converted into an array that contains 4000 values/period of the amplitude of the residual signal.

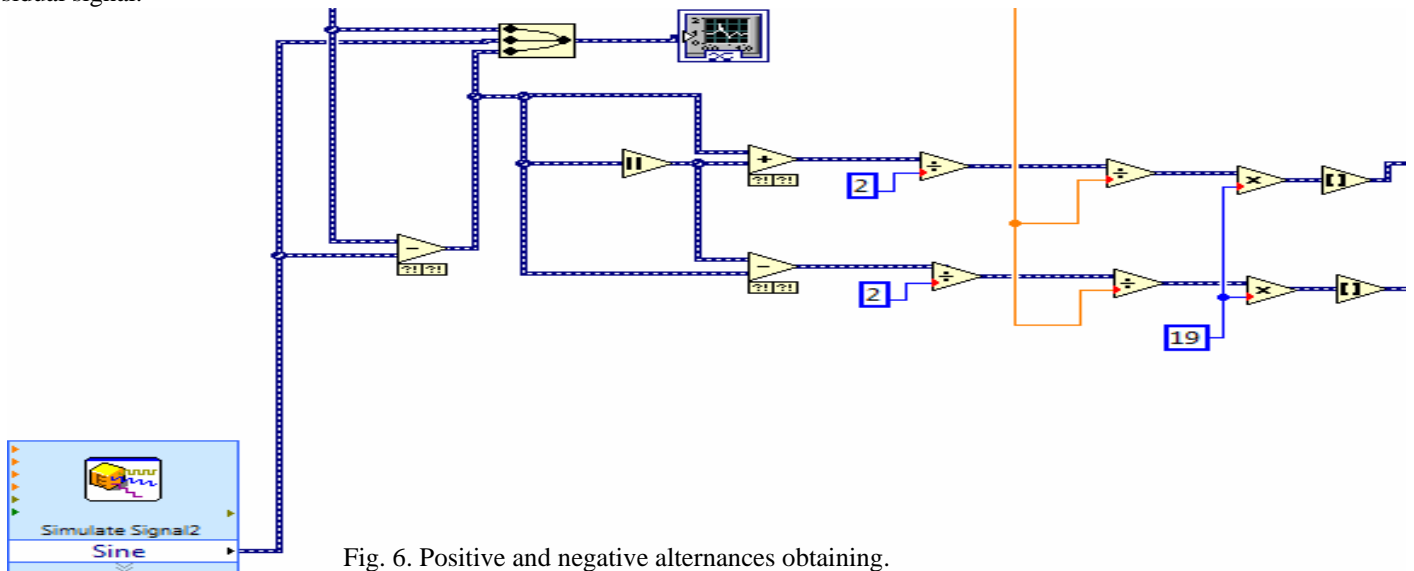


Fig. 6. Positive and negative alternances obtaining.

Using an Index Array block, there are extracted 200 samples/period. For each sample, it is using a Pulse Pattern block that generates a pulse with given width and amplitude.

These 400 pulses are concatenated in a value vector that is converted in dynamic data: one for the positive modulator and one for the negative modulator.

These two signals are sent to Data Acquisition Board pinouts for commanding IGBT transistors. The waveform of these signals can be followed on the front panel of the application.

Generation of the residual currents  $irez1\pm$ ,  $irez2\pm$ ,  $irez3\pm$  is accomplished using mathematical blocks. With blocks from the same LabVIEW palette are attained the positive and negative alternances of the residual signals.

The residual currents on each phase is width modulated using a virtual instruments created in this scope. There are resulting six modulators: three for positive alternances and three for negative alternances.

The variation of the signal width at the outputs of the modulators follows the amplitude of the residual currents and the results are presented in figures 9, 10, 11.

All six IGBT command signals are sent to data acquisition board pinouts using DAQ Assistant block.

In order to obtain a continuous functioning, all elements of electric scheme are introduced in a While structure. Loop condition represents the Stop button placed on Front Panel.

Distorted signal for one phase is simulated as a square signal from a signal generator with  $N=4000$  samples / period and a sampling rate  $f=200\text{kHz}$ .

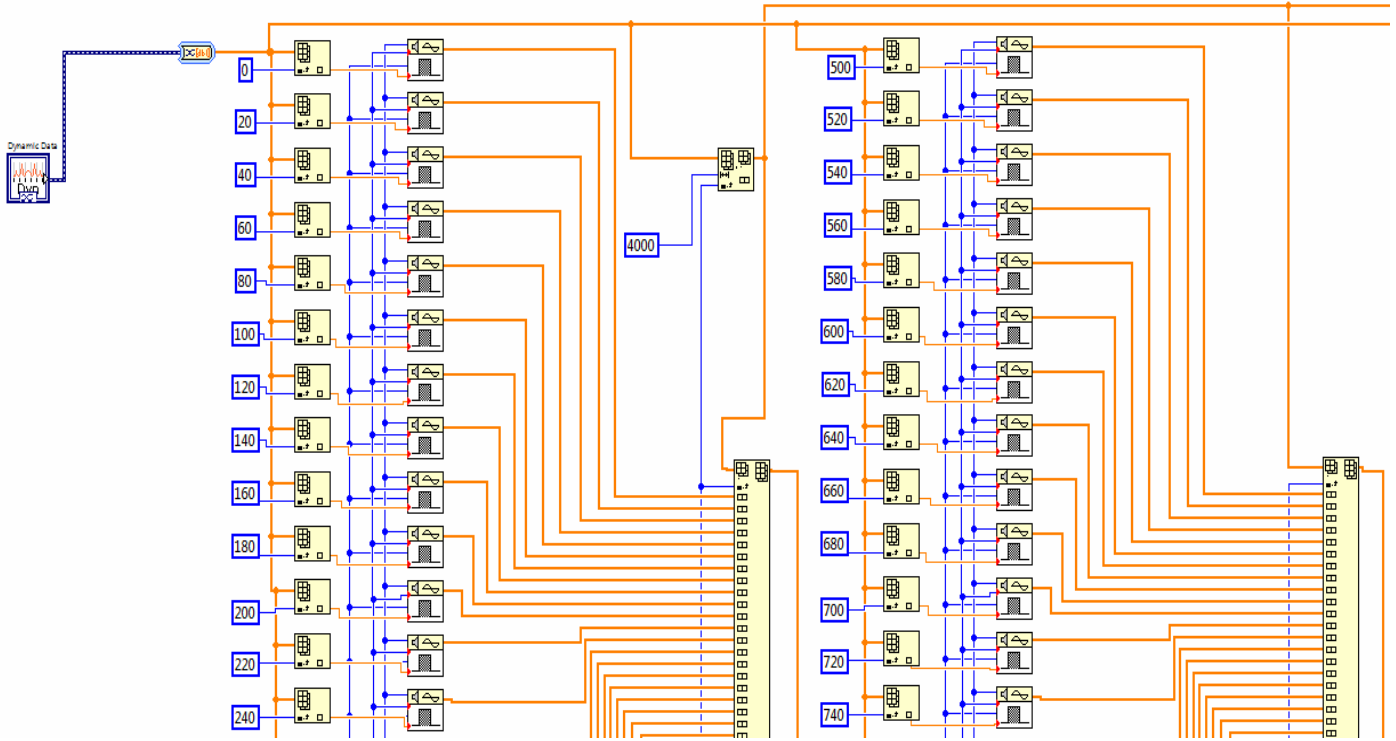


Fig. 7. Pulse width modulator (part of it).

Figure 9 presents the variation of the IGBT single phase command signals that are sent to DAQ pinouts with duty cycle for the distorted signal of 25% and  $f=50\text{Hz}$ .

Figure 10 presents the variation of the IGBT single phase command signals with duty cycle of 50% and  $f=50\text{Hz}$ .

Figure 11 presents the variation of the IGBT single phase command signals with duty cycle of 75% and  $f=50\text{Hz}$ .

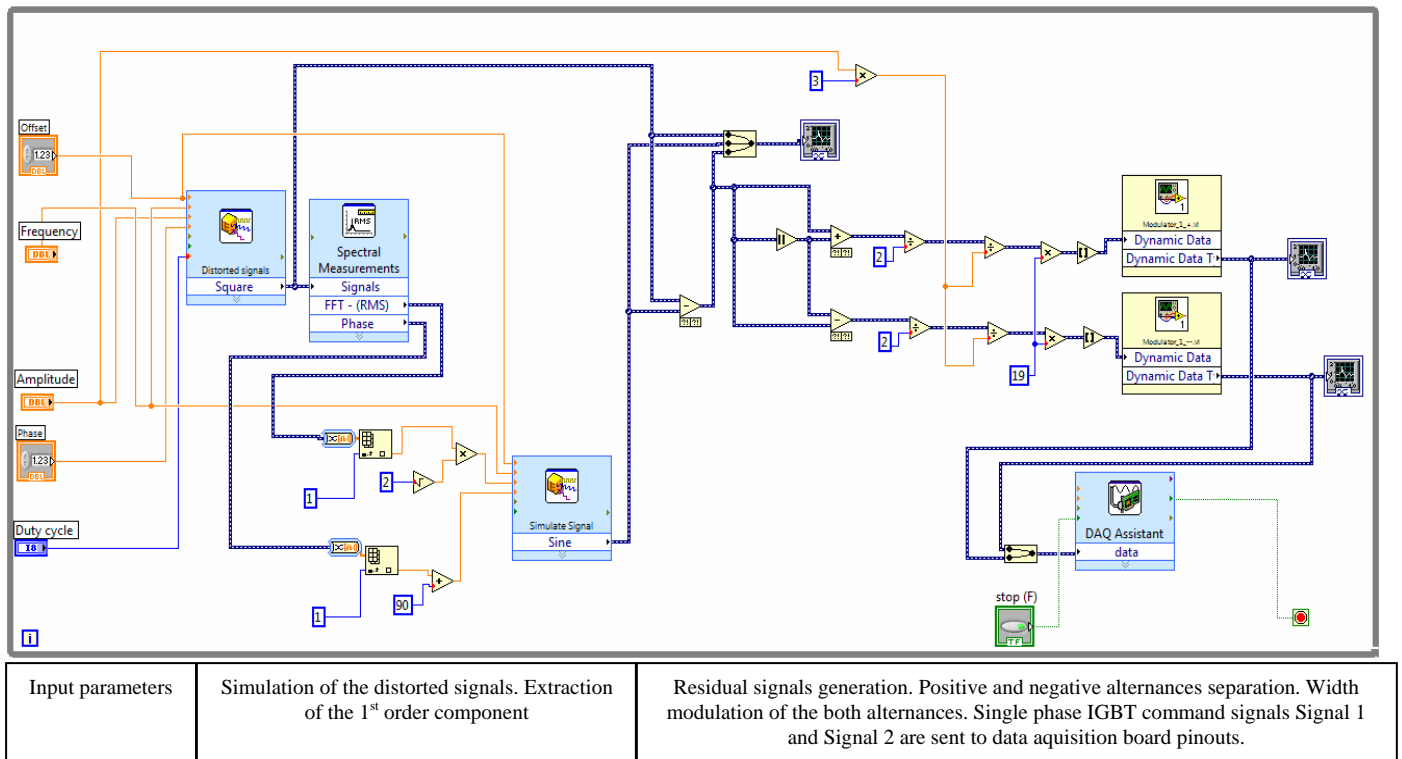


Fig. 8. Single phase IGBT command scheme.

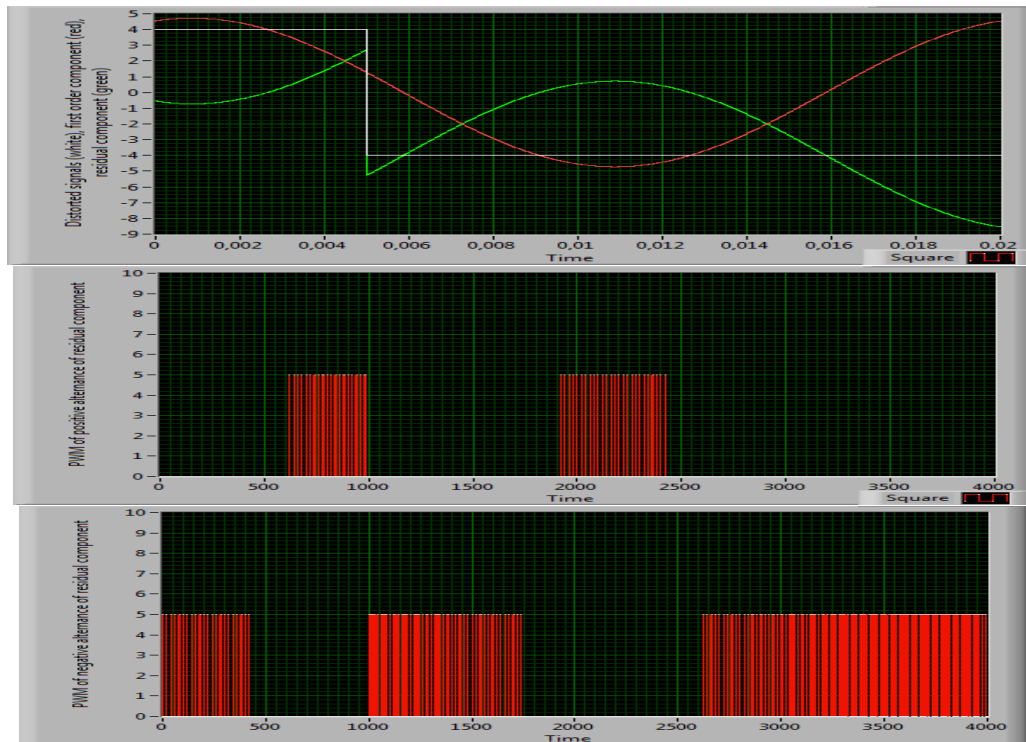


Fig. 9. LabVIEW generated signals (duty cycle=25%). .

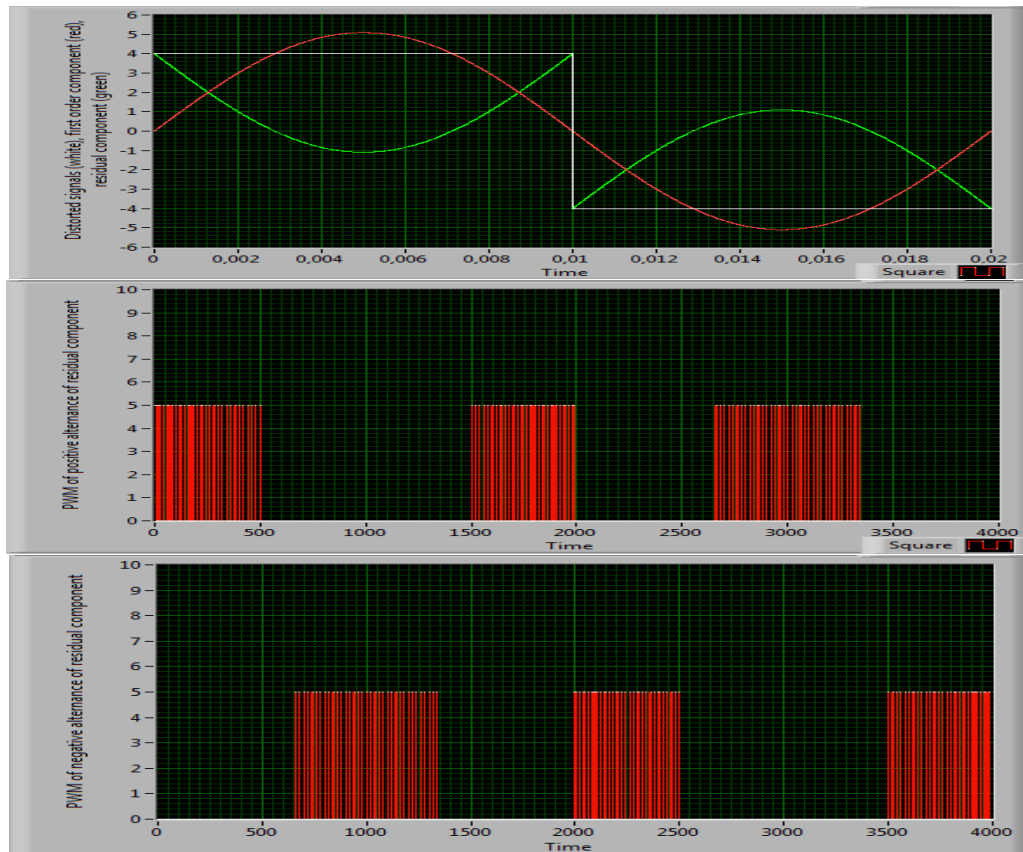


Fig. 10. LabVIEW generated signals (duty cycle=50%). .

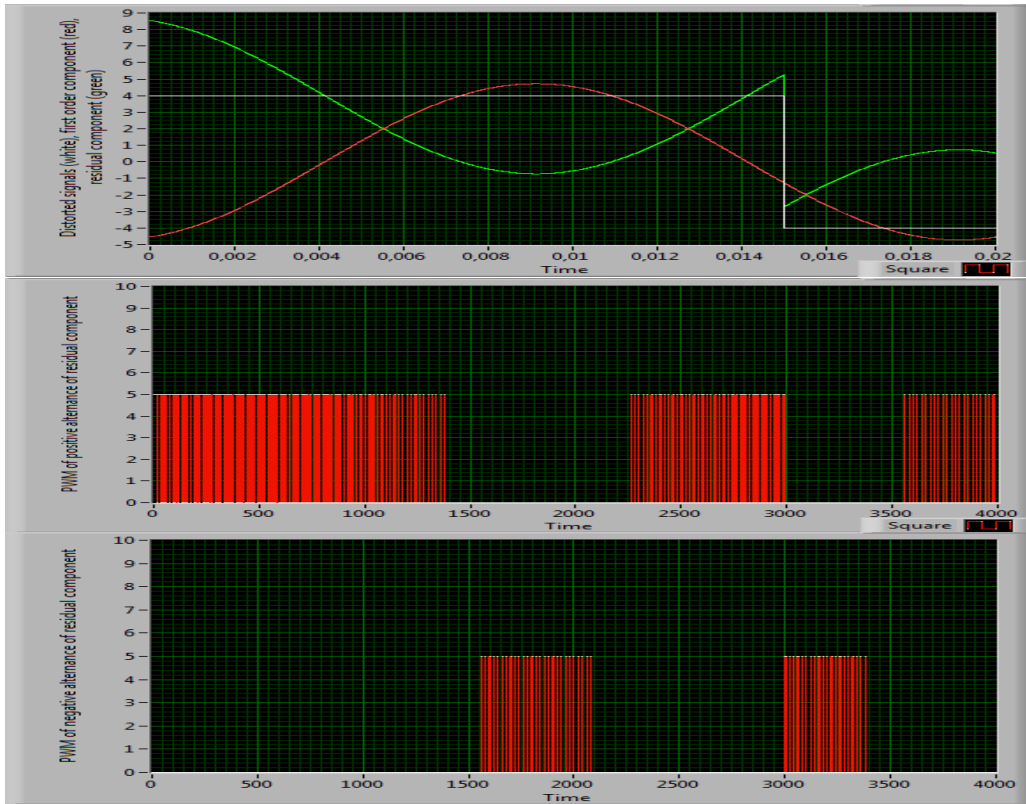


Fig. 11. LabVIEW generated signals (duty cycle=75%).

III. SHUNT ACTIVE FILTER DESIGNING (SINGLE PHASE)

The command signals generated by LabVIEW scheme are available at the pinouts of data acquisition board. For one phase they are noted with Signal 1 and Signal 2. These two width modulated signals command two IGBT transistors using two optocouplers (fig. 12). IGBT transistors are supplied to a continuous double voltage source  $V_{DD}$ . The single phase signal that will be injected in power system is available on resistance R terminal.

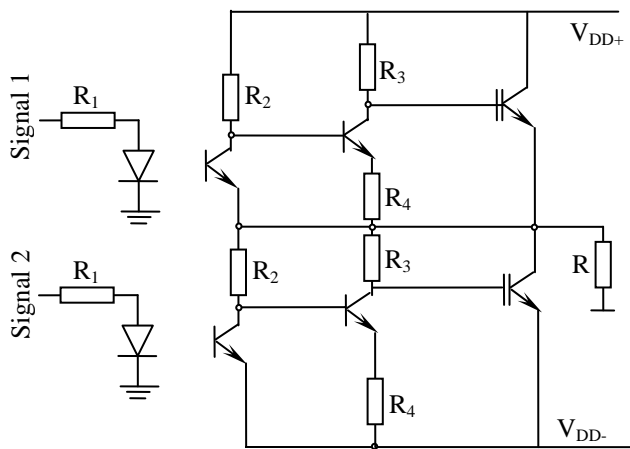


Fig. 12. Single phase IGBT electric scheme.

Figure 13 presents the variation of the single phase IGBT output signal with duty cycle=25%. The output signal is filtered using a capacitor.

Figure 14 presents the variation for duty cycle=50% and figure 15 presents the variation for duty cycle=75%. Figure 16 presents the variation for duty cycle=25%, the signal is not filtered.

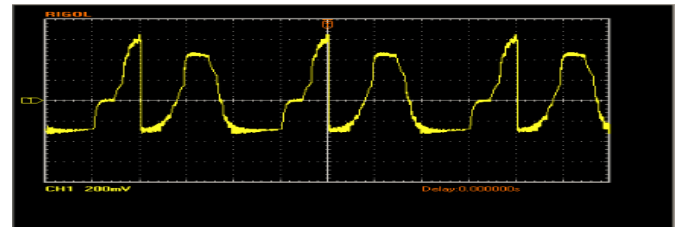


Fig. 13. Single phase IGBT output filtered signal for duty cycle=25%.

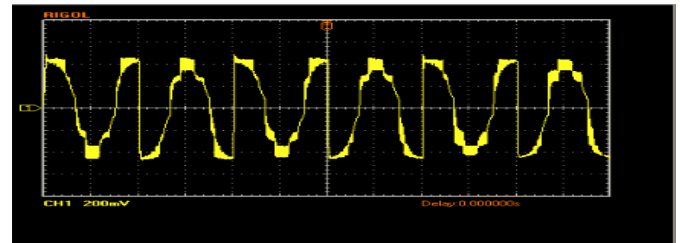


Fig. 14. Single phase IGBT output filtered signal for duty cycle=50%.

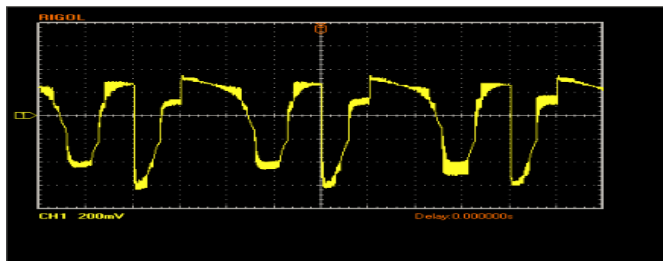


Fig. 15. Single phase IGBT output filtered signal for duty cycle=75%.

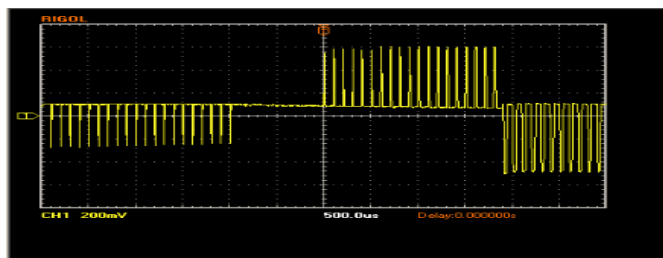


Fig. 16. Single phase IGBT output not filtered signal for duty cycle=25%.

#### IV. CONCLUSIONS

This paper presents a method to obtain the compensation currents that are necessary to be injected in power system during the functioning of a nonlinear load. The designed filter consists in six IGBT transistors that are commanded using a LabVIEW electric scheme command through the pinouts of a data acquisition board.

The authors followed the compensation currents obtained at the IGBT outputs using an oscilloscope for different values of distorted signal duty cycle.

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